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Natural convection of water–CuO nanofluid in a cavity with two pairs of heat source–sink ☆

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ABSTRACT

Natural convection in a two-dimensional square cavity filled with a water–CuO nanofluid is numerically studied. Two pairs of heat source–sink are considered to cover the entire length of the bottom wall of the cavity while the other walls are thermally insulated. The nanofluid is assumed to be homogenous and Newtonian. The governing differential equations are discretised by the control volume approach and the coupling between velocity and pressure is solved using the SIMPLE algorithm. A comparison study is presented between two cases with different arrangements of the two pairs on the bottom wall. The effects of Rayleigh number and solid volume fraction of the nanofluid on the heat transfer rate have also been examined. The results show that regardless of the position of the pairs of source–sink, the heat transfer rate increases with an increase of the Rayleigh number and the solid volume fraction.

1. Introduction

The study of natural convection in square cavities has attracted considerable interest amongst researchers due to its increasing engineering applications such as the cooling systems of electronic devices. The advantageous characteristics of natural convection cooling systems are their simplicity, reduced noise, manageable size and minimum cost. A comprehensive review of the studies on natural convection in cavities has been presented by Ostrach [1]. Recently, Deng [2] classified these studies into four groups: 1- Cavities with a pair of source–sink [3]; 2- Cavities with one source and multiple sinks [4]; 3- Cavities with multiple sources and one sink [5]; and 4- Cavities with multiple sources and multiple sinks [6]. Most of these studies deal with fluids having relatively low thermal conductivities. The latest technologies in advanced electronic devices, however, require coolants with enhanced cooling performances.

It has been shown that the addition of nanoparticles with relatively higher thermal conductivity to the base fluid results in an increase of the thermal performance of the resultant mixture (nanofluid) [7]. The thermal performance of different types of nanofluids has been the subject of many recent studies [8]. Most of these studies have argued that higher thermal conductivity can be achieved in thermal systems utilising nanofluids. Some researchers, however, argue that the dispersion of nanoparticles in the base fluid may result in a substantial decrease of the heat transfer [9]. The enhancement or mitigation of the heat transfer of nanofluids may be because of the formulas used for their thermal properties [10,11]. A comprehensive nanofluid simulation study should take account of the structure, shape, size, aggregation and anisotropy of the nanoparticles as well as the type, fabrication process, particle aggregation and deterioration of nanofluids.

The study of natural convection in cavities filled with nanofluids has also been reported in the literature [12–20]. Most of these studies dealt with natural convection generated by a pair of heat source and heat sink on the walls of the cavity. To the best knowledge of the authors, no studies that investigate the natural convection in nanofluid-filled cavities with multiple heat sources and heat sinks have been reported in the literature. This problem may be encountered in the cooling systems of many electronic devices. Hence, the present study numerically examines the natural convection in a square cavity filled with a water–CuO nanofluid and with two pairs of source–sink located at the bottom wall of the cavity.

2. Problem description

Fig. 1 shows the schematic diagram of a two-dimensional square cavity with a side length of L = 5 cm that is considered in this study. Two pairs of heat source–sink cover the entire length of the bottom wall of the cavity while the other walls are thermally insulated. The heat sources are maintained at a constant temperature (T_h) that is higher than that of the heat sink T_c. The temperature of the heat sink is assumed to be $T_c = 300\ K$. The cavity is filled with a homogenous water–CuO nanofluid. The water and the spherical CuO nanoparticles ($R_s = 38.9\ nm$) are in thermal equilibrium. Table 1 presents the thermophysical properties of water and CuO nanoparticles. The

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